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WASTE TREATMENT FOR SMALL FLOWS

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Cincinnati, Ohio 45226

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For Presentation at the 1971 Annual Meeting
AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS

Washington State University
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WASTE TREATMENT FOR SMALL FLOWS*

J. F. Kreissl**

It can be safely stated that the main thrust of waste treatment research in recent years has been concerned with large municipal and industrial sources. The logic to such an approach is obvious from Figure 1. Since approximately 75 percent of the total population of the United States is located in urban areas, large municipal systems represent the most profitable form of pursuit in terms of pollution abatement. The economics of municipal wastewater collection have been discussed by Smith and Eilers(1). The cost of sewer construction on a per capita basis was found to be related inversely to the population density as shown in Figure 2. Interpolation of these costs to rural area conditions of lower densities and larger lot sizes and consideration of needs for force mains and pump stations due to topographical conditions leads one to the conclusion that costs become prohibitive.

Similar "economics of size" have been computed for the treatment of municipal wastes. Figure 3 shows the costs for such a plant treating from 1 to 100 MGD of municipal wastewater(2). A well-run plant of this type can be expected to remove 85 to 95 percent of the organic and particulate matter from wastewaters. It should be noted that nitrogen and phosphorus removals are usually minimal in such an installation. In many instances water quality standards will require relatively complete removal of phosphorus and, in some cases, nitrogen to protect the receiving stream and increase the cost of treatment significantly.

The average community served by a sewer system and treatment plant has a daily flow of 7 to 10 MGD. The breakdown of costs per capita paid by the 1968 user are shown in Table I(1). The total figure of $19.80 does not represent the actual cost of these facilities because of the general lag in sewer charges assessed by municipalities. In addition, these costs may be significantly higher for a more diffuse rural area where more sewerage per capita is required.

Other negative factors for rural wastewater problems include the intermittent flow patterns of wastewaters. Although municipal flows also have distinct diurnal flow variations, individual and small groups of homes will greatly accentuate the "spikey" nature of the pattern. One must also consider that the need for proper operation of any waste treatment facility will require some amount of physical attention or instrumentation. Some special problems of individual home wastewaters also exist which further differentiate them from those of a municipal nature. In general, individual sources exhibit much stronger wastewater in terms of suspended solids, organic matter, nitrogen, phosphorus, and grease, as shown in Table II. This is due to the fact that municipal systems are subject to infiltration from ground- and storm-water as well as numerous other types of dilution.

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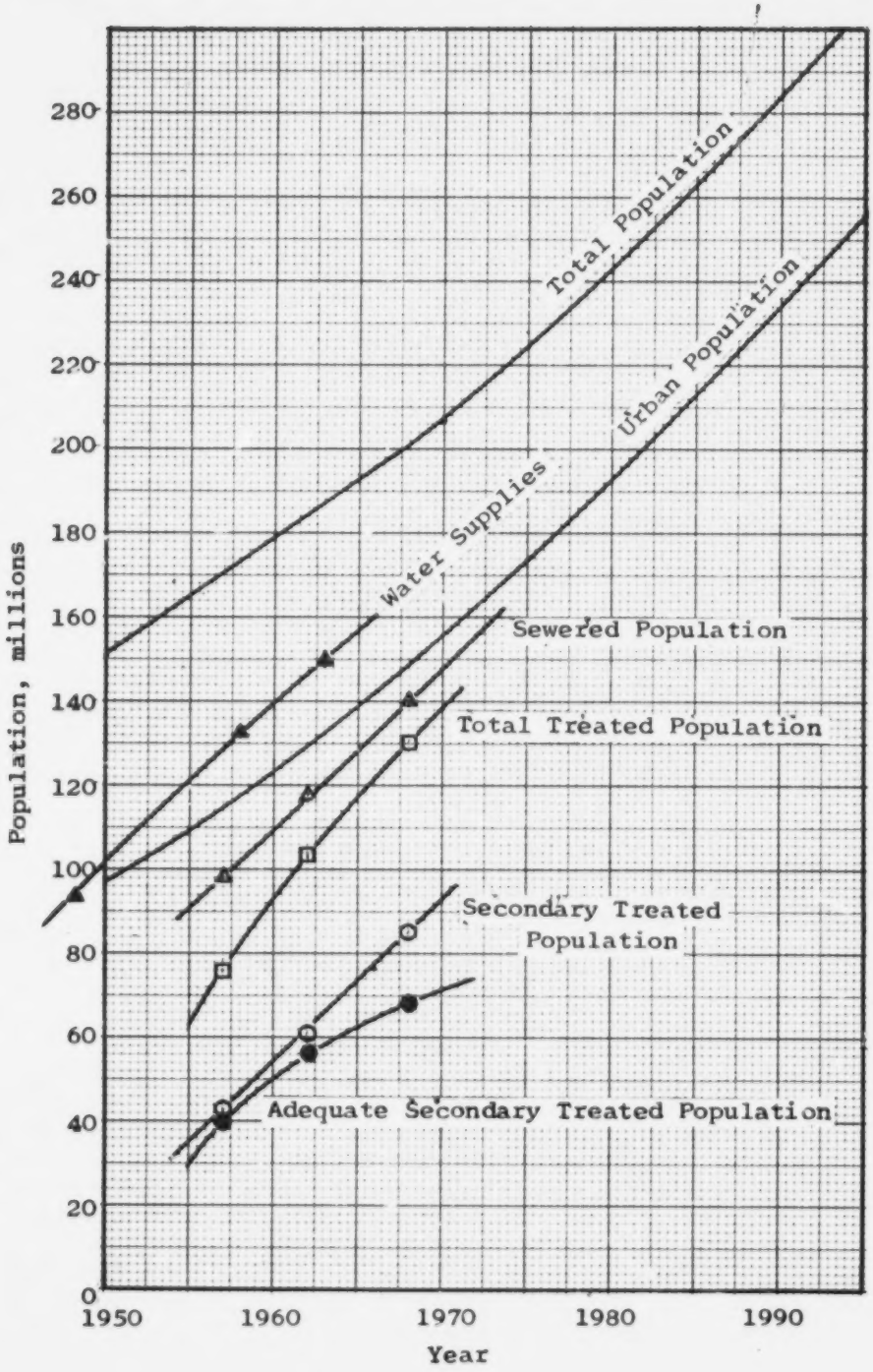


FIGURE 1
STATUS OF MUNICIPAL WASTEWATER TREATMENT FACILITIES
IN THE UNITED STATES

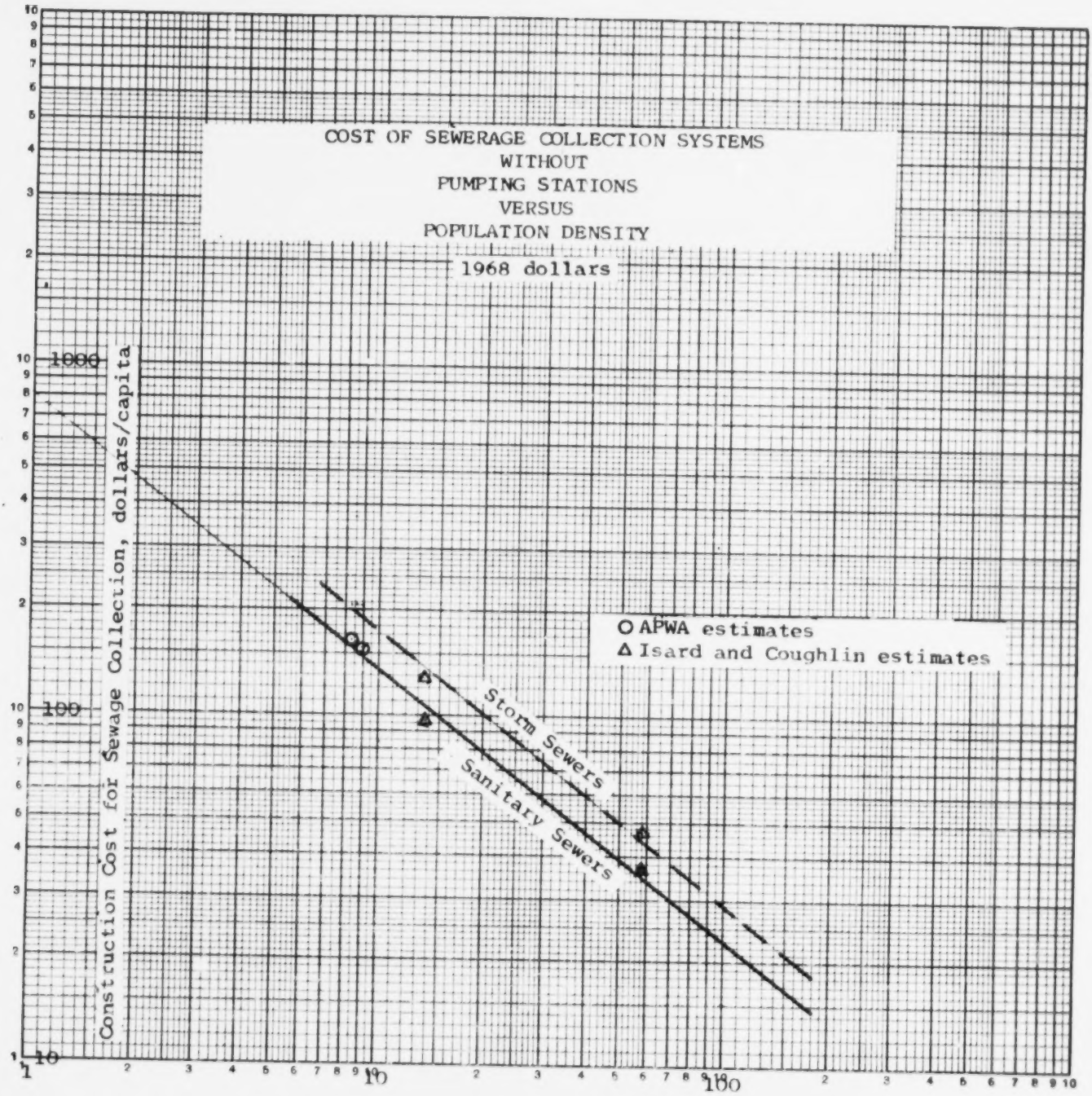

COST OF SEWERAGE COLLECTION SYSTEMS
WITHOUT
PUMPING STATIONS
VERSUS
POPULATION DENSITY
1968 dollars
Construction Cost for Sewage Collection, dollars/capita
1000
100
10
1
10
100
Storm Sewers
Sanitary Sewers
O APWA estimates
Δ Isard and Coughlin estimates
Population density, persons/acre

FIGURE 2

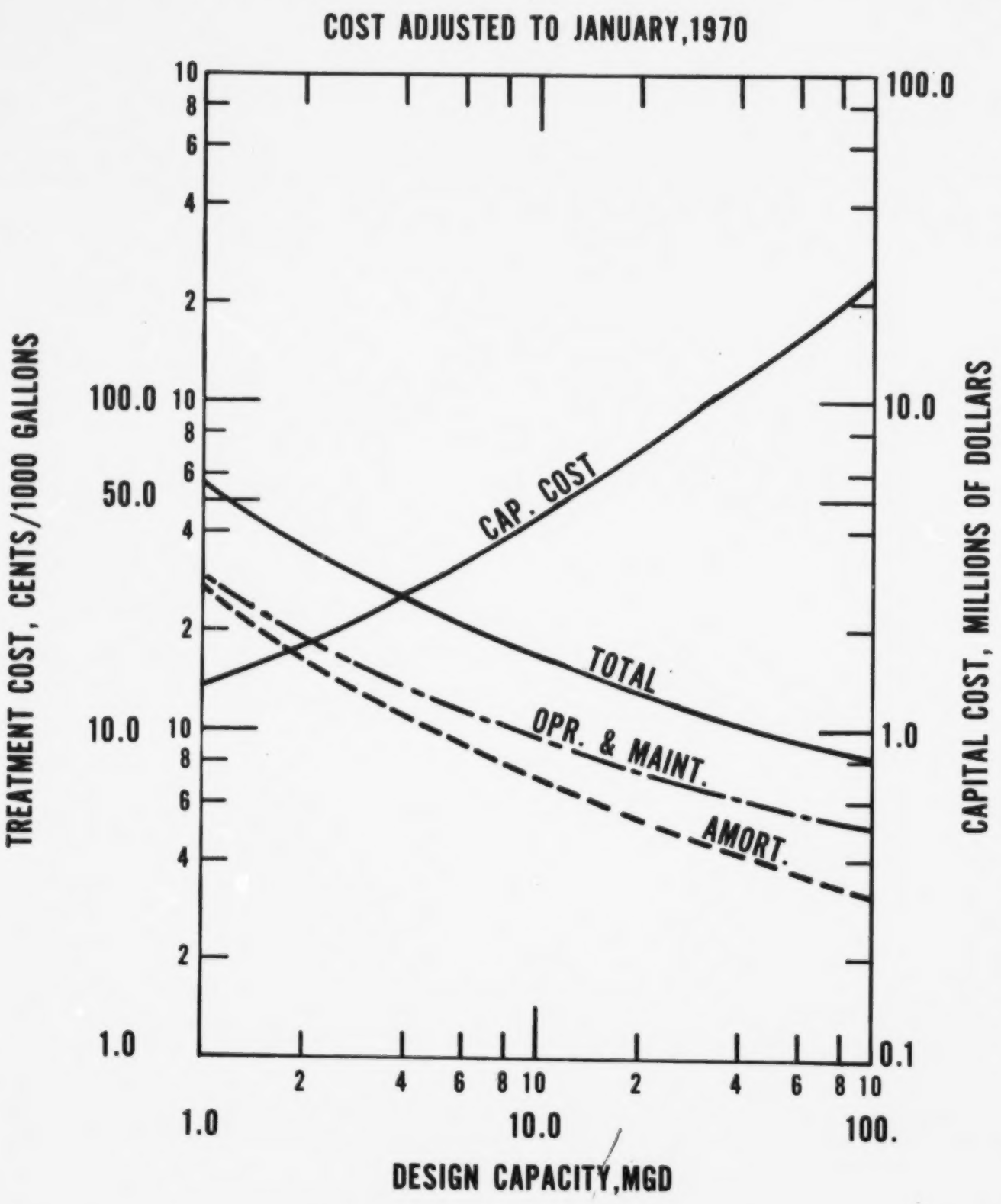


FIG. 3 **ACTIVATED SLUDGE PLANTS**

TABLE I

TOTAL COST OF SEWAGE COLLECTION AND TREATMENT IN 1968
ON A CONTINUOUS CASH FLOW BASIS
1968 dollars/capita/year

Amortization Cost		
House Connection	$1.38	
Municipal Sewers	$8.64	
Interceptors and Outfalls	$2.46	
Treatment Plants	$2.83	
Total Amortization Cost	$15.31	
Current Expenses		
Municipal Sewer Maintenance		$0.86
Treatment Operation and Maintenance		$1.55
Customer Service and Accounting		$0.71
General and Administrative		$1.37
Total Current Expenses		$4.49
Total Cost of Municipal Collection and Treatment	$19.80	

TABLE II
WASTE CHARACTERIZATION

PARAMETER (UNITS)	TYPICAL MUNICIPAL SEWAGE	HOUSEHOLD WASTEWATER	
		W.GRINDER	W.O.GRINDER
SUSPENDED SOLIDS, mg/l	200	480	380
COD, mg/l	350	910	710
BOD_5, mg/l	210	490	435
TOTAL NITROGEN, mg N/l	33	105	84
AMMONIA, mg N/l	12	81	64
TOTAL PHOSPHORUS, mg PO_4/l	24	57	61
GREASE, mg/l	14	89	65

As these negative aspects become apparent, one might well ask what the answer to this problem might be. Surely, one answer is planning. In areas of growth around urban centers an official master plan of that region becomes an effective tool for determination not only of the physical layout of the area, but also for determination of sewerage needs. By constructing these facilities along with the housing structures, much difficulty is avoided. If interceptor sewers cannot be extended at the time of construction, it is a relatively simple matter to provide a temporary "package" waste treatment plant at the point of sewage discharge from the new development.

It is painfully true that master plans are generally scarce and limited to larger urban centers. In the absence of the physical criteria put forth in these documents there is a need to make decisions concerning wastewater problems. As a rule, it always is desirable to provide for central collection and treatment of wastes. The costs previously noted must be taken into account along with the socio-political considerations as to future development of the area. Unfortunately, where insufficient regulation is involved, many developers have opted for individual systems because of their more clearly defined cost to the individual home (5). In many areas such systems are not suitable due to the soil's inability to accept the volume of wastewater generated or due to their proximity to lakes and streams creating the possibility for pollution. The suggested distances between the various components of an individual household sanitary system are illustrated in Table III. In addition, the size of an absorption field is dependent on the results of preliminary percolation tests. It is readily apparent that the use of a private well coupled with a poor soil permeability will require prohibitively large land areas for individual homes.

Numerous situations exist where individual systems are the only feasible method of waste treatment. These are generally due to the inherent isolation of the dwelling. Small systems include such things as farms, isolated rural homes, fishing cabins, hunting cabins, and the like. Larger installations which are prevalent include ski resorts, highway rest areas, park facilities, schools and hospitals, work camps, and numerous other isolated facilities producing large quantities of wastewater.

Individual Homes

Household water use is a function of the number of residents, standard of living, utilization of climate, and personal habits. Estimates vary from 20 to more than 100 gallons per capita per day (gpcd) when lawn sprinkling is excluded. (5) Water usage per capita is generally found to be inversely proportional to the number of residents per dwelling due to certain relatively constant household requirements, and directly proportional to the standard of living because of increased utilization of water-consuming modern appliances. A recent study (5) estimated that an average home of two adults and two children has a water-use breakdown as shown in Figure 4. This survey also concluded that water used in bathing, toilet flushing, and laundering can be economically reduced by more than 35 percent with commercially available devices. A partial listing of the feasible devices available for water savings in the home are shown in Table IV

TABLE III

MINIMUM DISTANCE BETWEEN COMPONENTS OF SEWAGE DISPOSAL SYSTEM

COMPONENT OF SYSTEM	HORIZONTAL DISTANCE (FEET)				
	WELL OR SUCTION LINE	WATER SUPPLY LINE (PRESSURE)	STREAM	DWELLING	PROPERTY LINE
BUILDING SEWER	50	10	50		
SEPTIC TANK	50	10	50	5	10
DISPOSAL FIELD AND SEEPAGE BED	100	25	50	20	5
SEEPAGE PIT	100	50	50	20	10
CESSPOOL	150	50	50	20	15

FIGURE 4

AVERAGE HOUSEHOLD WATER REQUIREMENTS FOR A FAMILY OF 2 ADULTS AND 2 CHILDREN

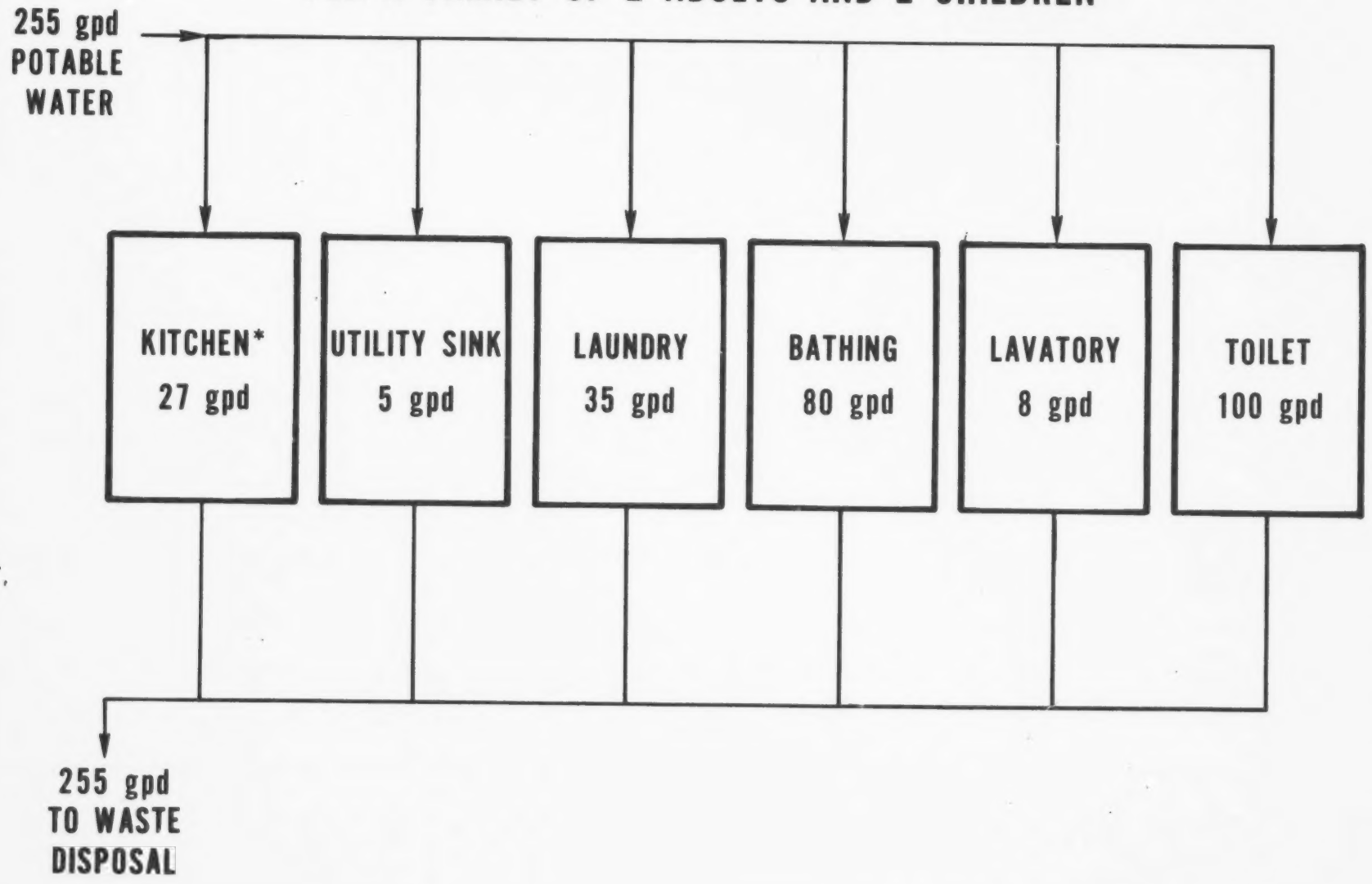


TABLE IV

WATER SAVINGS vs COST FOR PLUMBING DEVICES

	WATER SAVINGS		NEW CONSTRUCTION ESTIMATED COST		OLD CONSTRUCTION ESTIMATED COST	
HARDWARE DEVICE	gpcd	gpd	MATL.	INSTALLED COST	MATL.	INSTALLED COST
LIMITING FLOW VALVES FOR SHOWER	6	24	15	15	35	50
LIMITING FLOW VALVES FOR LAVATORY	0.5	2	25	25	45	68
LIMITING FLOW VALVES FOR KITCHEN SINK	0.5	2	25	25	45	68
AERATOR FOR LAVATORY AND KITCHEN SINK	0.5	2	2	2	2	2
DUAL CYCLE WATER CLOSET	17.5	70	10	10	100	130
WASHING MACHINE WITH LEVEL CONTROL	1.2	5	35	35	35	35

along with their estimated installation costs and water savings potential (5). Reduced water consumption will result in correspondingly high concentrations of pollutants. The effects of this situation on home wastewater treatment will have to be determined. A study of this type is proposed for funding by the Environmental Protection Agency in the near future.

The traditional means of waste treatment for individual homes is the septic tank-soil absorption system depicted in Figure 5. In cases where these installations are properly designed and soil conditions are satisfactory, good results are obtained when proper servicing of the system is afforded. Failure of these systems is most often exhibited by a failure of the soil absorption system. Causes of such failures may be due to inadequate soils, improper leach-field construction techniques, or malfunctioning septic tanks due to poor construction or inadequate servicing. Some variations on the septic tank-soil absorption system have been marketed. A limited amount of data have been generated on these systems at this time, however.

A number of people feel that a good aerobic effluent will significantly reduce the area needed for soil absorption fields. With superior organic and solids removal, the two major causes of soil clogging are reduced. A number of manufacturers offer these individual home aerobic treatment devices to the public. Although they are more expensive than the simpler septic tanks, their higher performance level may justify the expenditure.

The number of septic tanks in use today is estimated at more than 17 million, including cesspools. Some 5 to 10 million primitive systems, i.e., the pit privy and similar devices, are still in use. Between 20,000 and 30,000 home aerobic treatment systems are estimated to be in use presently (5). A typical septic tank installation includes a collection line from the house; a septic tank; a distribution box, in some cases; and a soil absorption system. Cutaway drawings of the septic tank and absorption systems are illustrated in Figures 6 and 7. The septic tank is basically a settling tank and low-rate digestion system allowing for solids settling (sludge) and floating (scum) with concomitant liquefaction of solids. Solids digestion, however, does not completely eliminate these materials, so periodic removal of accumulated solids must be accomplished. Depending on the construction and location of these units, this can be a difficult and offensive operation. Clogging of the soil absorption system is the usual result of system failure. The best available compilation of septic tank-soil absorption information and design and maintenance data is the Public Health Service Publication No. 526, Manual of Septic Tank Practice. Septic tank-soil absorption systems vary in cost according to a number of variables. Septic tank purchase and installation cost is reported to be about $400, while the cost of soil systems vary widely. Maintenance costs for septic tank cleaning every 2 to 4 years are estimated at $14/year. Some approximate installation costs for absorption fields based on soil types are (5):

FIGURE 5

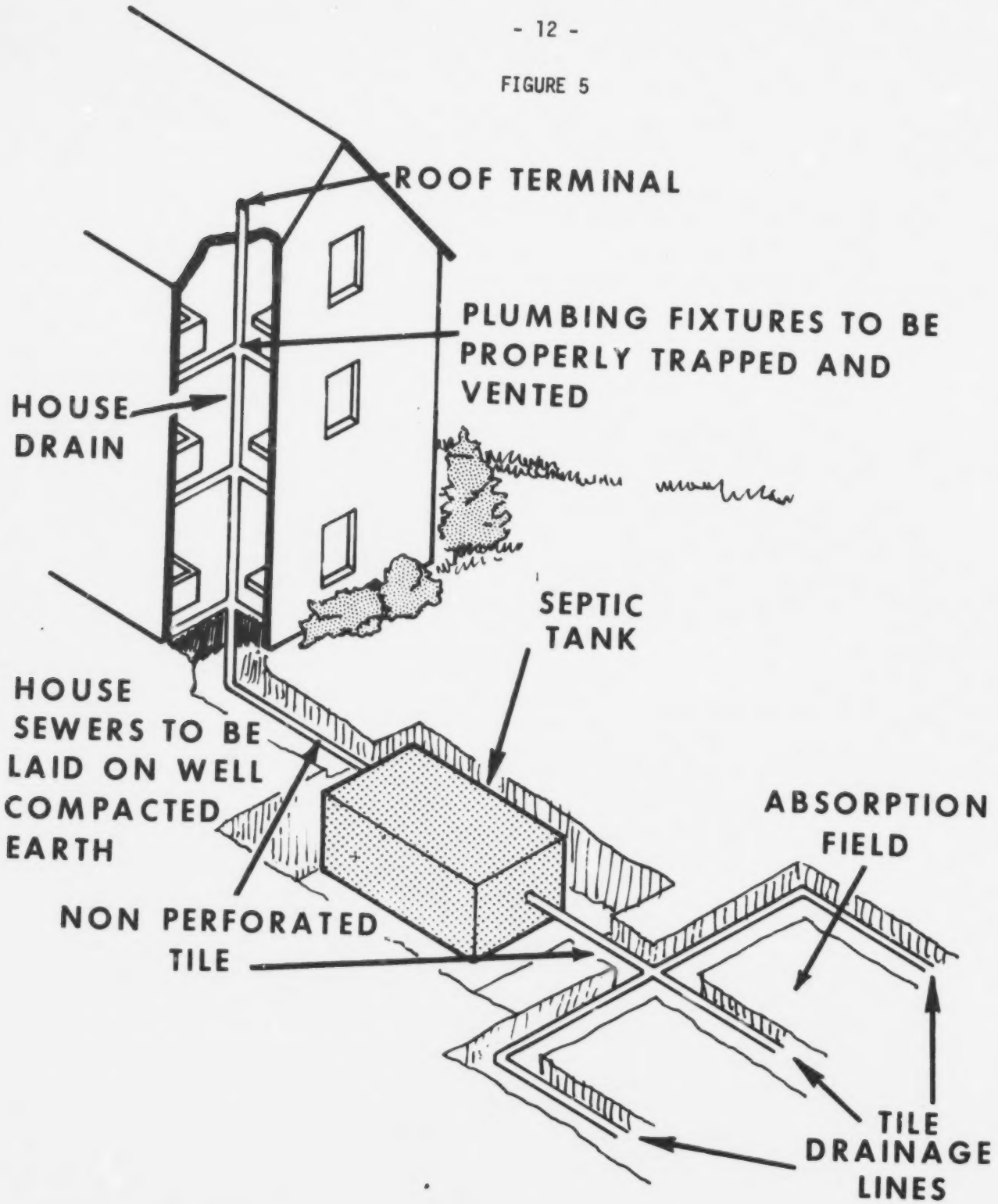
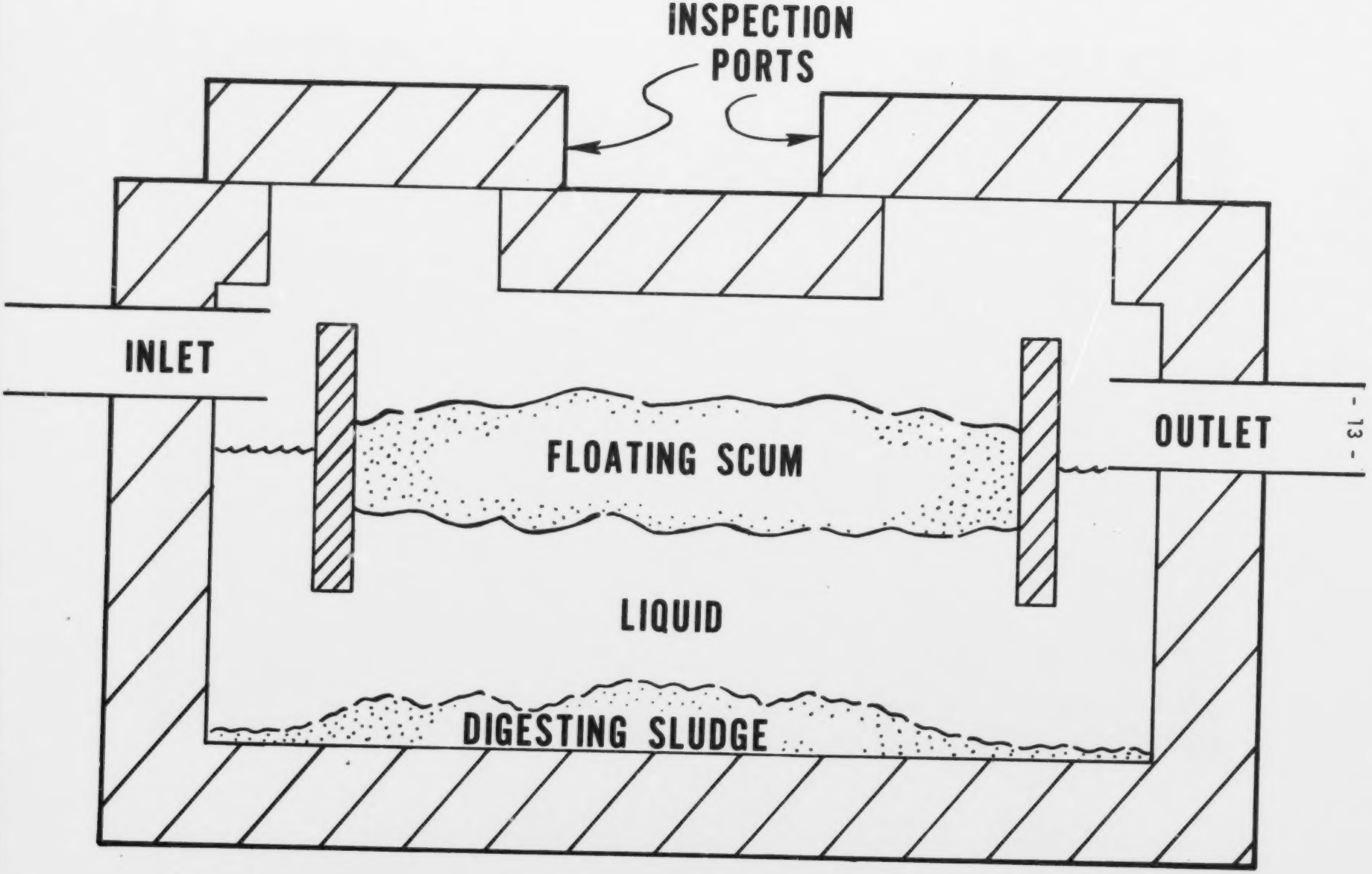

ROOF TERMINAL
PLUMBING FIXTURES TO BE PROPERLY TRAPPED AND VENTED
HOUSE DRAIN
SEPTIC TANK
HOUSE SEWERS TO BE LAID ON WELL COMPACTED EARTH
ABSORPTION FIELD
NON PERFORATED TILE
TILE DRAINAGE LINES

FIGURE 6


INSPECTION
PORTS
INLET
OUTLET
FLOATING SCUM
LIQUID
DIGESTING SLUDGE

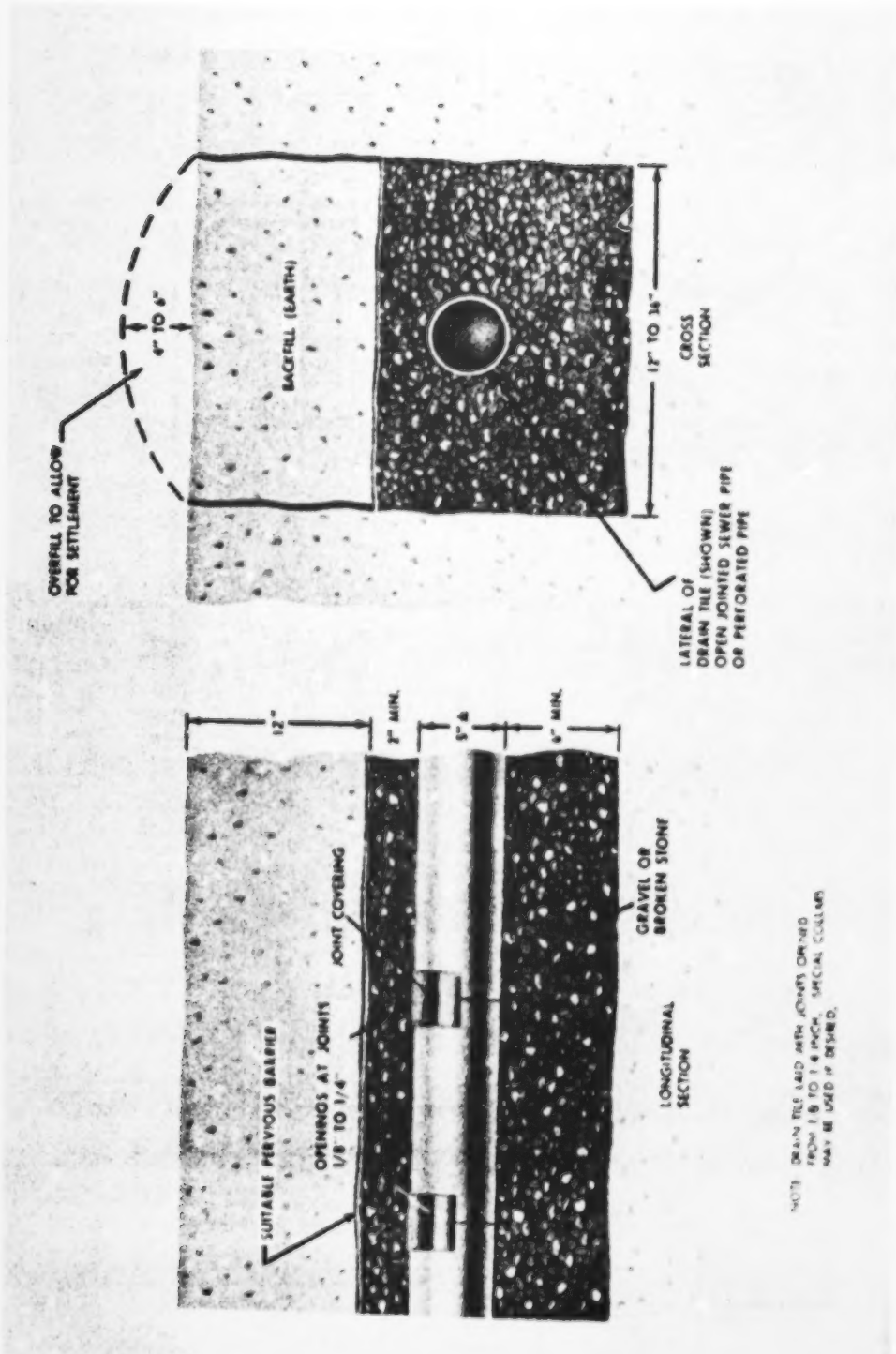


Figure 7—**Absorption trench and lateral.**

Soil Suitability	Soil System Installation Cost
Good	$200 - 300
Fair	500 - 750
Poor	1600 - 2400

The septic tank is capable of removing about 50 percent of the organics and about 70 percent of the suspended solids present in the raw wastewater.

Aerobic treatment systems for individual homes generally are required to utilize subsurface soil systems. Technically, their product should be capable of meeting municipal effluent quality in terms of solids and organic matter but their susceptibility to shock loads and toxic chemicals combined with an absence of operating personnel usually will require subsurface disposal. Surface disposal requires disinfection and other necessary treatment to meet public health and water quality standards. Widespread opinion suggests that aerobic effluents should allow a significant reduction in the size requirement of the soil disposal field, but insufficient data on this subject have thus far prevented extensive utilization of this theory. Most systems claim results of approximately 90 percent suspended solids removal without the use of filters and disinfection systems on the effluent. Some typical systems are shown in Figures 8 and 9, These systems are necessarily more expensive than the simpler septic tank.

A number of newer systems are being developed by manufacturers based on more sophisticated treatment principles. A definite need exists for treatment systems which can be added to existing septic tank systems to obtain improved performance as well as for systems which can be installed as alternative treatment systems with superior removal capabilities. A study proposed for the near future is designed to determine the necessary reliability of new individual home wastewater treatment systems and to pursue the development of a model code for the regulation of all individual home systems.

Centralized Treatment

Previous discussion has pointed out the difficulty of centralized treatment in rural areas. The major problem of individual household wastewater systems is to dispose of wastewaters in safe manner with minimum hazard to public health (7). With larger contributing sources such as schools, hospitals, resorts, and parks or a small community system, the major problem becomes one of reliable and effective waste treatment. So-called "Package plants" can be utilized for many of these locations because some form of operational manpower can be provided. Such plants have become generally acceptable to most regulatory agencies because of advantages accruing to the ease of enforcement when compared to innumerable small individual systems discharging to surface waters. In light of the previous discussion of potential costs the multiple-dwelling waste disposal system should be broken down into the two phases, collection and treatment. Because of the previously noted cost of providing gravity sewers for sparsely populated areas,

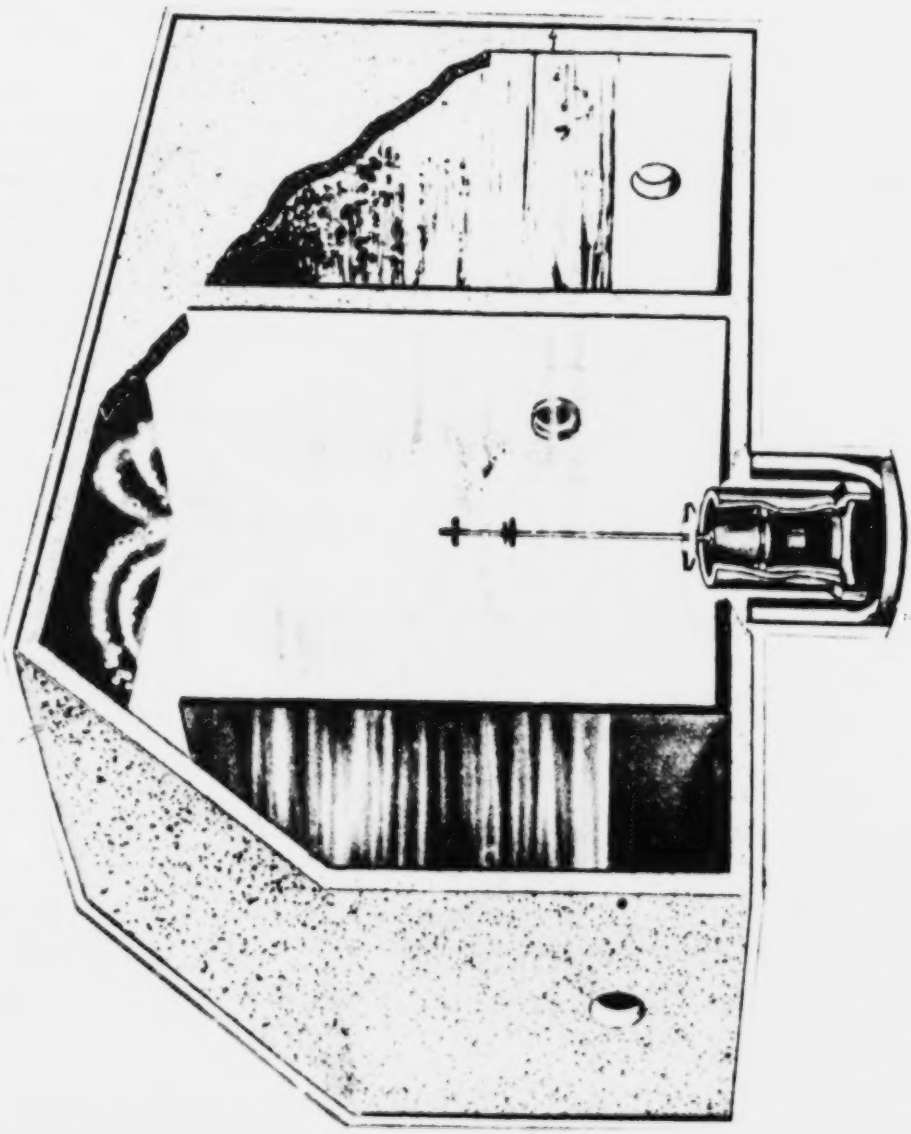


Figure 8. TYPICAL INDIVIDUAL HOUSEHOLD AEROBIC SYSTEM

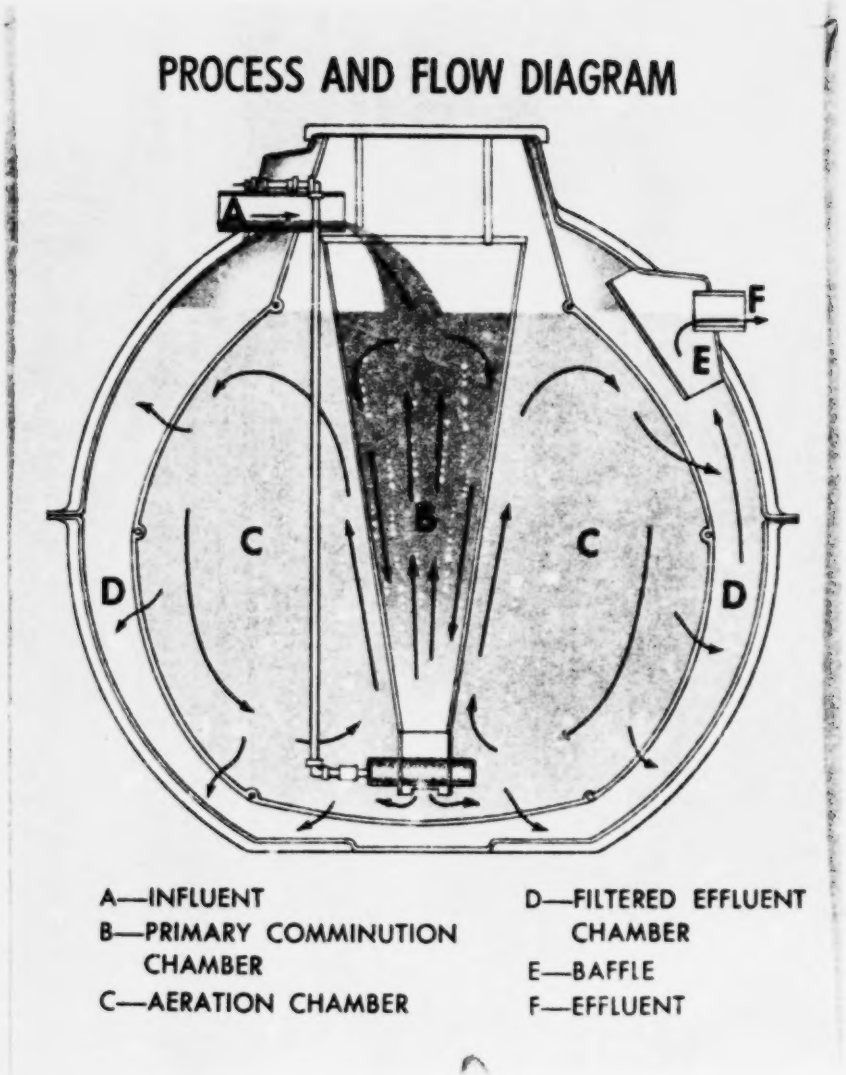


Figure 8. TYPICAL INDIVIDUAL HOUSEHOLD AEROBIC SYSTEM

the Environmental Protection Agency has supported two projects on the development of low-cost pressure sewer systems. One of these, Grandview Lake, Indiana, has been reported on at this session. The other is located in Phoenixville, Pennsylvania. The Phoenixville project involves fewer residences, different pump-grinder units, a more difficult terrain and no treatment of the wastes. The system is shown schematically in Figure 10.
Ground sewage is pumped through 1-1/2 and 2-inch-diameter PVC lines at an average flow of 11 gpm under pressures of up to 50 psi. The pump-grinder units shown in Figures 11 and 12 are rated to pump a minimum of 8 gpm into a 60 psi system and a maximum of 15 gpm at atmospheric pressure. Emergency bypasses to septic tanks are provided at the pump-grinder units in case of a malfunction. The collection pipe was laid at a depth of 30 inches which is below the frost line. In the Phoenixville situation the low elevation and high water table made conventional sewers prohibitive and individual home systems impractical. Evaluation of this system is due for completion before the end of the year.

A vacuum collection system has also been considered because of its associated water-savings potential. This system has been withdrawn from the market at this time due to some mechanical difficulties, but it is expected to return in the near future. If pressure and/or vacuum systems prove successful, many problems associated with individual home treatment may be alleviated. Possibly the most difficult problem is the fact that more than one-half of the land area of the United States is not suitable for disposal of wastewater. Where feasible, centralized collection and treatment with surface discharge may open up much of this land for development or, at least, reduce required lot sizes to increase the tax base of the area. The other difficulties of soil-clogging, predicting infiltration rates, septic-tank cleaning, and public health problems could be eliminated in many areas. It is relatively assured that centralized treatment will become economically feasible for significantly greater numbers of homes as a result of these developments. Once economic data on these systems are available, the engineering evaluation of the relative economics of centralized treatment and collection systems versus individual home treatment and disposal systems becomes a relatively straightforward computation if both systems are deemed feasible for implementation. Superimposed on any such evaluation will still be the socio-economic, political, and other superseding considerations, but these ultimate decisions will be made easier with more precise information on the engineering alternatives.

Treatment of the larger wastewater flows is usually accomplished by package plants based on biological treatment principles. Although most are some form of an activated sludge or dispersed-growth system, there are also systems based on a fixed-growth or trickling filter design. Numerous varieties of these plants are offered by a large number of manufacturers, but most are either extended aeration or contact stabilization systems as illustrated in Figures 13 and 14, respectively. In some instances where toxic compounds are found in the waste, space limitations exist, or extreme flow variations occur, biological systems are not capable of providing proper treatment (3). In these cases, some form of physical-chemical treatment may be required in place of a conventional biological unit. These systems have the advantage of being able to operate on an on-off mode without a significant degradation in effluent quality. Phosphorus removal is also inherent in most designs, so that effluent phosphorus standards can be met where required.

FIG. 10

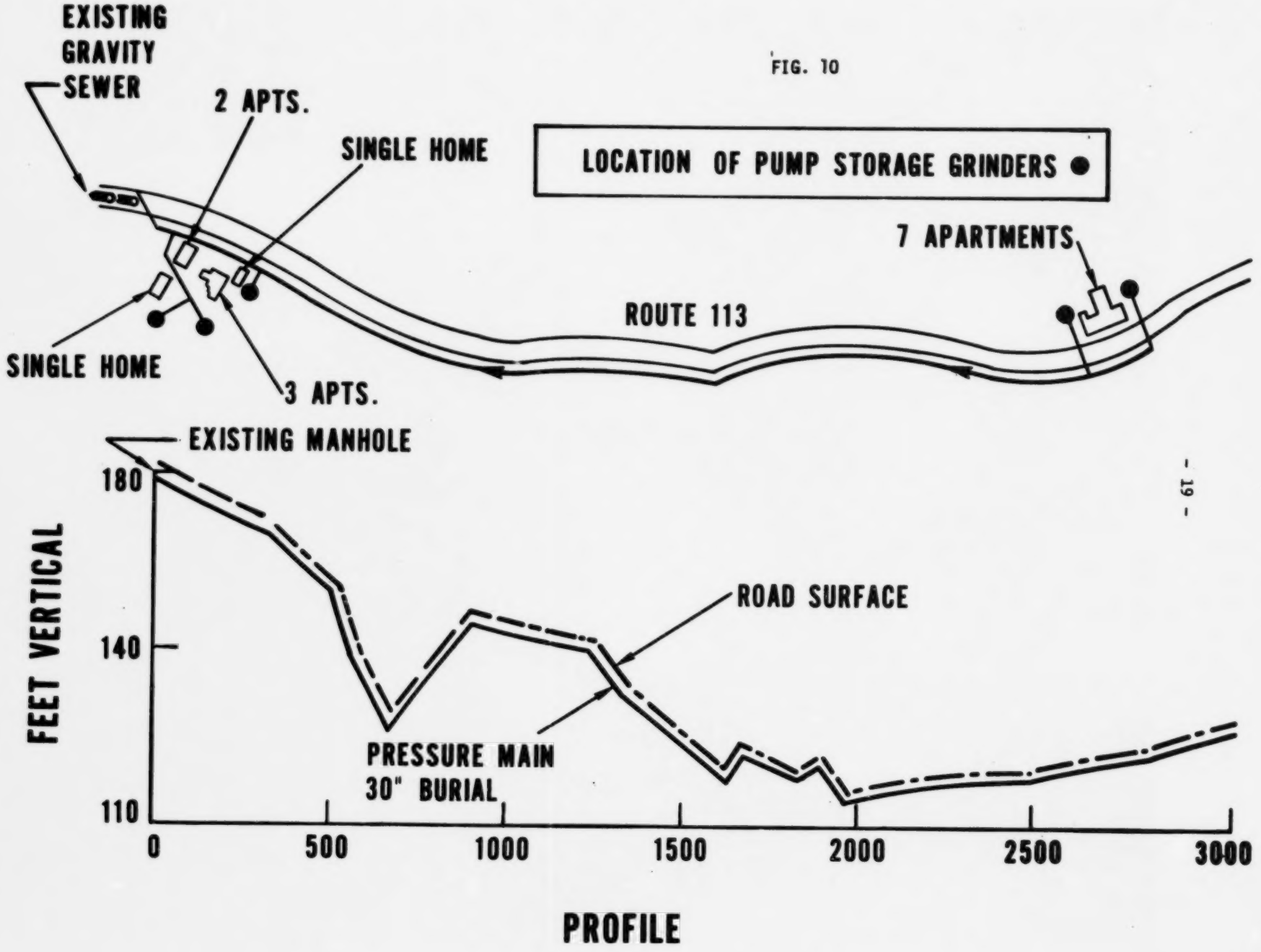

EXISTING GRAVITY SEWER
2 APTS.
SINGLE HOME
LOCATION OF PUMP STORAGE GRINDERS ●
7 APARTMENTS
ROUTE 113
SINGLE HOME
3 APTS.
EXISTING MANHOLE
180
140
110
FEET VERTICAL
ROAD SURFACE
PRESSURE MAIN
30" BURIAL
0
500
1000
1500
2000
2500
3000
PROFILE

FIGURE 11

FIGURE 12

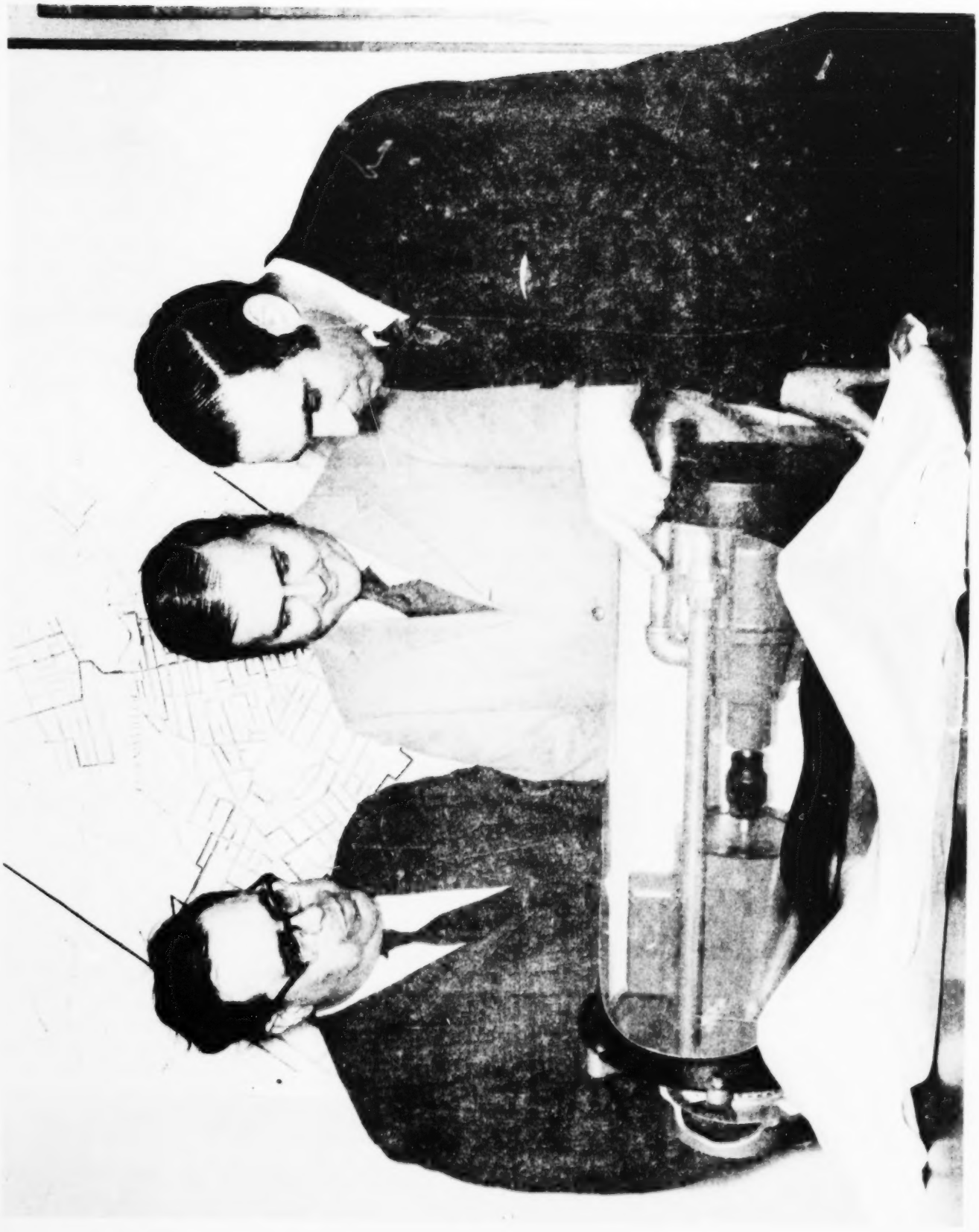


FIGURE 13

EXTENDED AERATION

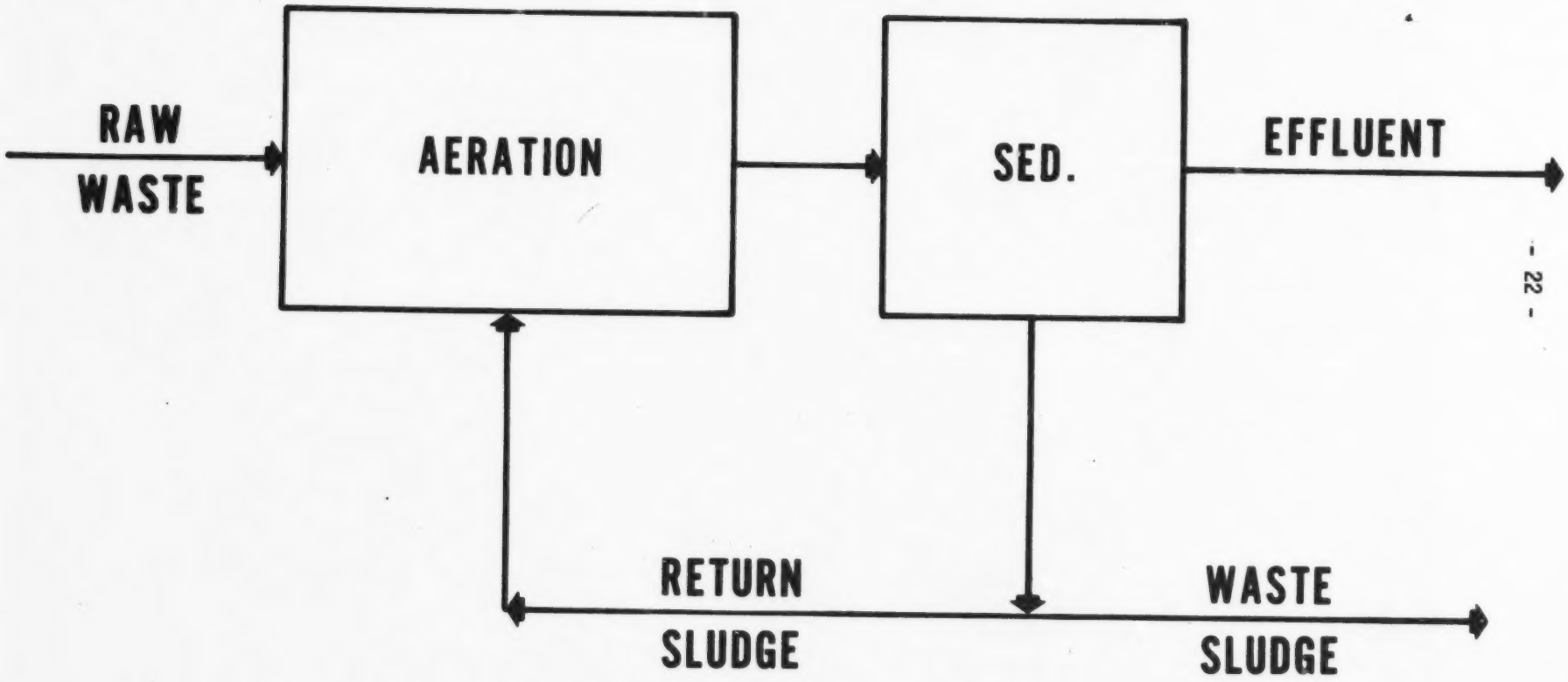
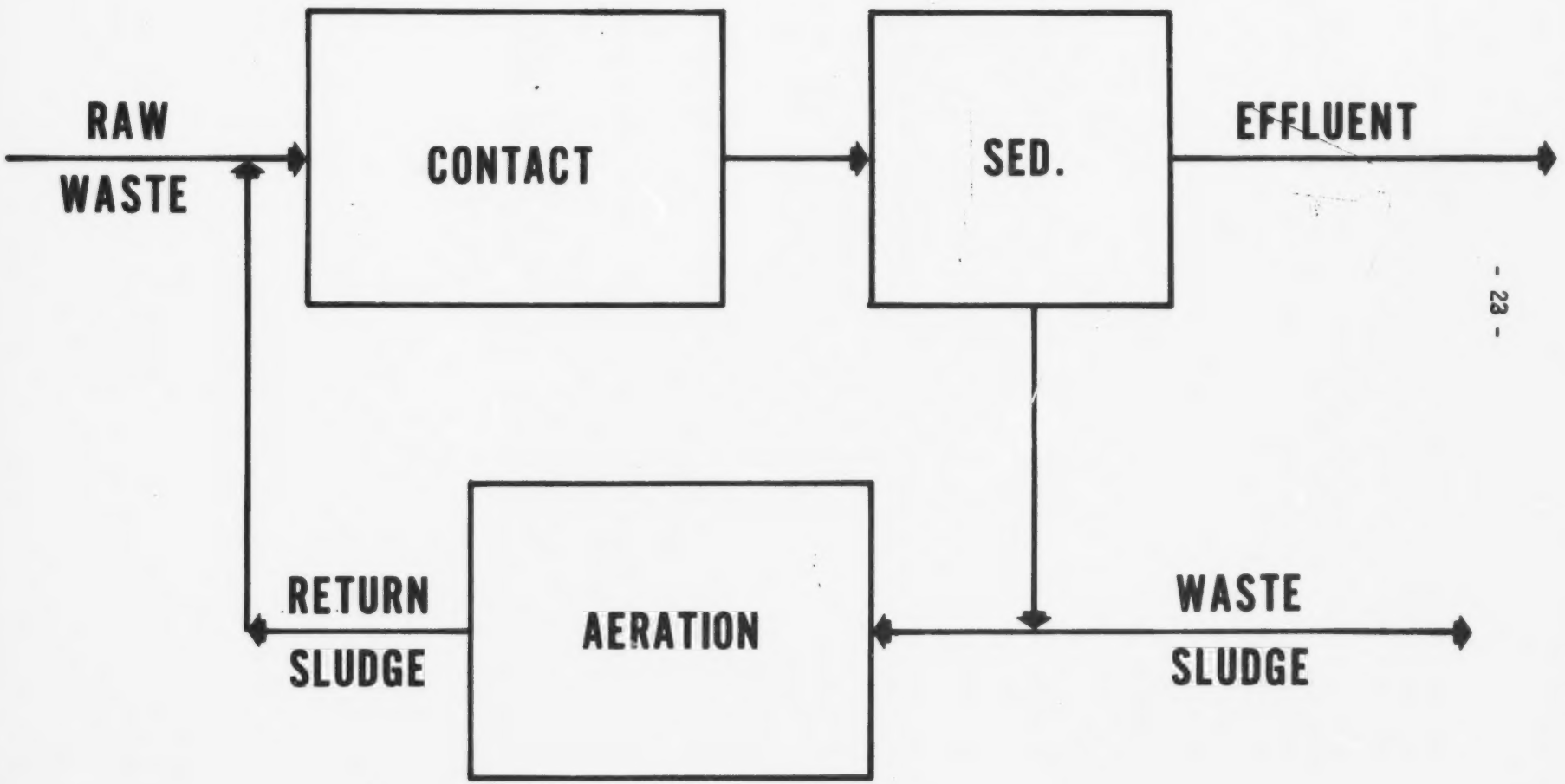


FIGURE ~~13~~ 14

CONTACT STABILIZATION



The Environmental Protection Agency is pursuing development of physical-chemical systems in order to be able to meet the needs of locations where biological treatment is inadequate.

The EPA program in the area of small systems or individual home wastewater treatment has thus far been concerned with the development of low-cost collection systems as well as the development of a state-of-the-art survey of flow reduction and wastewater treatment for individual homes. Projects in the near future are concerned with evaluation of household waste treatment systems and the development of model codes and reliability requirements for those systems. Attempts will be made on a continuous basis to utilize advances in processing and control techniques from larger systems for the development of improved methods for the treatment of household wastewaters.

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